WAR MEDICINE AND SURGERY

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SOFT TISSUE INJURIES.

INJURY to the soft tissues is frequently accompanied by injury to the bones. These combined lesions are not specially discussed in the present article, however, since it is the bony injury that usually takes priority in the treatment.

Soft tissue injuries occur mainly in the limbs, the buttocks and the shoulders. They are very common, both in peace and in war, and every surgeon is familiar with much that is known about them. Consequently, this account is restricted to seven subdivisions which are either somewhat novel or somewhat controversial: (a) excision and *débridement* of wounds; (b) primary suture; (c) chemotherapy; (d) immobilization; (e) skin grafting; (f) infection of recent wounds; and (g) wound healing. The subject of traumatic shock is omitted, because it has been dealt with in a previous article; otherwise it would have been given a prominent position, because of its importance and its rapidly increasing literature.

EXCISION AND DÉBRIDEMENT OF WOUNDS.

The free and somewhat inaccurate use of these important terms has resulted in a great deal of confusion. Some have used them as synonyms; some have gone to the other extreme and thought that *débridement* implies no more than the removal of wound débris. The explanations of medical etymologists have further confused the issue, but, with the publication of clear statements in such authoritative texts as that of Hamilton Bailey,[1] the words have acquired generally accepted meanings.

By excision of a wound is meant the meticulous removal of non-viable tissue. This can profitably be done only in the early stages after wounding, when there is no natural protective tissue barrier to be broken down. In the early stages the bacteria have not begun their local invasion, and the wound is only potentially infected. The duration of this golden period for operation is variable, since it is affected by such factors as the site of the wound, the virulence and extent of the infection and the use of early sulphonamide therapy. It has commonly been reckoned as lasting about eight hours; but some would extend it to seventy-two hours, especially in cases in which sulphonamide has been applied locally, immediately after the wounding. The duration of the period is something which has to be assessed clinically, in each case, from the circumstance of the injury and the appearance of both wound and patient. The aim of wound excision is to remove all foreign bodies, all tissue deprived of its blood supply and all tissue macroscopically contaminated; the resulting channel should therefore have a wall with active blood supply and only light infection. Excision is inadvisable in cases of superficial multiple wounds, and is unnecessary in through-and-through wounds with little disruption of tissue.

Débridement is the procedure undertaken when local invasion of the tissues by bacteria has already begun. The aim is to open up the tissues, so as to facilitate drainage; any readily accessible foreign bodies and necrotic tissue are removed as well, but this has to be done without infringement on the surrounding inflammatory zone. It is the only safe operative interference to use in older wounds, since, if these are excised, the effect is to produce a suppurating wound of larger size.

Another term used in the literature is "revision of a wound". It corresponds to excision, as done by the practising surgeon, and was introduced by way of distinction from the more anatomically thorough excision done in experimental work on animals. The term has not won general acceptance.

The technique of wound excision has been carefully worked out. Preparation of the operation area is begun by protecting the wound and scrubbing the surrounding skin with soap and water. If oil or grease is present it can be removed with lard. Some wounds can profitably be flushed out with normal saline solution; in other cases this would only distribute the débris. The skin incision is made parallel to the axis of the limb or the main underlying muscle. The exposure must be generous. The skin itself is preserved as far as possible, so that the margin of the wound is merely trimmed. The superficial fascia is excised freely. The deep fascia must be thoroughly opened up, because the damage in the muscle layer is frequently widespread, and the deep fascia must not be allowed to hide this damaged area from view or to prevent it from being drained. Muscle requires most thorough excision. Cut ends sometimes retract away from the wound, and these must be found and dealt with. Excision of muscle is adequate when fibres are reached which can contract on stimulation and which bleed when cut. This criterion must be followed even if it involves the removal of a muscle or group of muscles, as, for example, when a large muscular branch of an artery has been destroyed; otherwise massive necrosis occurs.

It will readily be seen that it is muscle tissue which requires most radical treatment. Tendons resist infection, and can survive even with a restricted blood supply. Bone fragments are removed only when they are completely detached from the periosteum. Important neuro-vascular

bundles, of course, have to be carefully conserved, and the chief special requirement of the operator is that he should have sufficient anatomical knowledge to comply with this stipulation. If a main artery has been destroyed by the injury, primary amputation may have to be undertaken; this is wound excision carried to its logical conclusion.

In the excision of a wound, a sharp knife is used, rather than scissors, since the knife causes less trauma. For similar reasons the artery forceps must have narrow blades, and the tissues must be handled with great gentleness. Fine-grade silk or cotton, rather than catgut, is used for ligatures, since the absorbable material causes a marked tissue reaction which is favourable to infection. Hæmostasis is essential.

Primary Suture.

All authors are agreed that there are certain wounds which may be closed by primary suture. This procedure is permissible whenever the surgical treatment has been early enough and thorough enough to ensure that the wound will not subsequently break down through infection. This means, in practice, that the patient must be operated on within eight hours; the surgeon and staff must be competent, and the facilities adequate, in order that the excision may be thoroughly done; buried sutures must not be used, except to close serous membranes; and the wound edges must be approximated without tension, and without the creation of dead spaces.

These conditions cannot ordinarily be fulfilled in the case of battle casualties, where the nature and extent of the injury are such that complete excision is difficult. To close an inadequately excised wound is to subject the patient to a risk of sepsis which may imperil his life. Primary suture of war wounds is, therefore, hardly ever attempted now, except in wounds of the skull, open wounds of the thorax, penetrating wounds of the abdomen and penetrating wounds of large superficial joints. In these cases the risk of primary suture has to be taken. The justification for the Army's disapproval of routine primary suture is that unfortunate results followed such treatment in the earlier stages of the present war. The problem is really one in which the procedure cannot be considered apart from the personnel, so that the best over-all results are achieved by standardization of the simplest procedure.

Chemotherapy.

Over the last decade there has been an increasing tendency not to hope for too much from antiseptics in the treatment of wounds, since the drug frequently does as much damage to the body defences as to the invading organism. This attitude has been modified, however, by the introduction of local sulphonamide therapy.

The results of the prophylactic application of sulphonamides to wounds are not spectacular. They are not comparable, for example, to the earlier successes achieved by chemotherapy in the treatment of pneumonia or puerperal sepsis. Several surgeons have issued warnings against the convenient hope that sulphonamide will compensate for inadequate excision of wounds. The warning is all the more necessary in that the drug diffuses poorly in necrotic tissue. Properly used, however, the sulphonamides are an important adjuvant to surgical measures.

Much work remains to be done on the best method of applying the sulphonamides to wounds. It is obvious that crushed tablets are not a suitable preparation, since, in the tablet, the active drug is mixed with starch and acacia. Sulphanilamide has been prepared in the form of microcrystals, which are soluble in plasma to the extent of 1,800 milligrammes per 100 cubic centimetres. This crystalline product is the best preparation available at the present time. Experimentally, it does not injure fibroblasts in tissue culture, and, clinically, there is no indication that it interferes with healing. These claims cannot be made for sulphathiazole or sulphadiazine powder, which tend to cake in a wound, and at times act as foreign bodies. This is unfortunate, since sulphanilamide is less active than either of these drugs against staphylococci, the colon bacilli and the organisms of gas gangrene. Sulphanilamide,

however, is very active against hæmolytic streptococci, which commonly cause wound infection. The sulphanilamide crystals can be sterilized by heating to 150° C. for two hours. This is a wise precaution, since tetanus has apparently been caused by the use of contaminated powder.

In the first-aid treatment of wounds, sulphanilamide may be applied freely without regard to dosage,[7] but, following excision, not more than ten grammes of the crystals should be placed in any one wound, and not more than twenty grammes in all the wounds of any one patient. Owing to the relatively high solubility of sulphanilamide, absorption from wounds is probably complete in about ten hours. The concentration reached in the wound exudate is some seven hundred times that which could be achieved by means of a safe oral dose. Further local applications of sulphanilamide are rather sporadic, since the necessity for resting the wound takes precedence over the desire to sprinkle it with antiseptic. More of the crystals are applied whenever the plaster is changed or the wound dressed.

Local administration is supplemented by oral. The best drug for routine use by mouth is sulphadiazine, since it is the least toxic; but sulphadiazine is not yet widely available, and the other sulphonamides may be used instead. The initial dose is four grammes; thereafter, four grammes per day are given for four days. At the end of the fourth day the dose is reduced, and at the end of the tenth day the drug is discontinued, provided the temperature is normal. This dosage is deliberately made rather low, because large doses of the drug should not be given by mouth when it is being used locally. Neglect of this principle has caused severe toxic symptoms.

Immobilization.

Rest is an essential part of the after-treatment of wounds, and is usually best provided by a plaster of Paris cast. The use of the plaster is one part of a method of treatment which was widely employed by Trueta in the Spanish War, and is sometimes named after him. The non-committal name of "closed plaster technique" is, however, more usual, since it avoids the controversy as to whether the method was fully known to earlier surgeons. It must not be thought that the immobilization in plaster is the essence of the treatment; it is just one step in a comprehensive therapy. Trueta places emphasis on excision of the wound as an essential preliminary to immobilization, and he states that no surgeon who is incapable of performing an elaborate excision should attempt to employ the closed plaster technique.[8]

The theoretical basis for the use of rest in the treatment of wounds is that it reduces the absorption of bacteria and their products. This is achieved, partly because lymph flow is at a minimum in resting tissue, and partly because the earliest defensive barrier raised by the body is readily disturbed by movement. This barrier consists only of a delicate fibrin layer, with local venous and capillary thrombi.

In regard to the plaster of Paris technique, it is further claimed that the cast exerts an even pressure on the wound, and so prevents local œdema, with its accompanying threat to the blood supply. If this reasoning is sound, it is important that the plaster should be unpadded, and that no window should be cut over the wound.

It is sometimes claimed that an additional advantage of the plaster cast is the prevention of cross infection. Unfortunately, this claim is not justified, since wounds have been shown to acquire fresh strains of bacteria while being treated by the plaster technique. The organisms probably gain entrance while the plaster jackets are being changed. It seems less probable that they should penetrate the plaster. On the other hand, bacteria move from within the cast to the outside with great facility. This is because the plaster is porous and the wound discharges are rapidly soaked up. Hæmolytic streptococci have frequently been obtained from the outer surface of a plaster and shown to belong to the same agglutinative type as those present in the underlying wound. In these cases a further hazard is created for other wounded patients in the neighbourhood.

Certain requirements must be fulfilled before the closed plaster technique can be safely used. The wound must have adequate drainage, and the blood supply of the part must not be in doubt. The most important requirement, however, is that continuity of treatment by the surgeon who applies the plaster must be assured. A surgeon who had not seen the wound would find difficulty in guarding against complications. He would be liable, on the one hand, to remove the plaster prematurely, and so lose its value, or, on the other hand, to court disaster by neglecting a spreading infection. In the normal course of events the plaster is not changed for three to six weeks. It is not usually necessary to remove the plaster because of discomfort or rise in temperature or lymphadenitis. The two main dangers are interference with the circulation and spreading infection. The former is more common in the lower limb than the upper, and great caution has to be shown with wounds of the thigh. The warning symptom is pain, and the warning sign, œdema of the distal part of the limb. The condition is not common, especially if the cast is carefully applied. It is combated by keeping the affected part elevated, and sometimes by splitting the jacket. Spreading infection is usually caused by incomplete drainage. It is indicated by listlessness, pain, increased temperature over the wound, raised pulse rate and persistently raised temperature. The treatment is to ensure adequate drainage of the wound, and then to reapply the plaster.

Two less serious disadvantages of the method are the tendency to septic dermatitis around the wound, and the repulsive, sour butyric smell that is invariably produced. The dermatitis is relieved if the wound is exposed to the air for a few days when the plaster is changed. The smell can be prevented from escaping by the use of deodorizing bags, which are made of cloth enclosing a layer of charcoal. These bags fit over the plaster like a loose stocking and are secured at the top by a draw-tape. They need not be applied until about one week after the plaster has been put on, and by that time it is no longer necessary to inspect the fingers or toes for circulatory disturbance. The bags do not obstruct the movements of fingers or toes. They save the application of a second plaster in those cases in which the smell would normally have required such a change.

The patients tolerate treatment by the plaster technique very well. They usually eat well and are comfortable; they are spared the horror of frequent painful dressings, and their general condition is usually excellent.

SKIN GRAFTING.

When extensive skin loss has taken place, treatment by excision and the application of plaster is not sufficient. Raw areas are left, and from the persisting granulations, fibrous tissue is gradually laid down. Infection, too, is usually present beneath the plaster, and this favours the production of further fibrous tissue. Such skin as does grow in from the epithelial edge is poor in quality; it is ridged, thickened and keloidal. The process of healing, moreover, is a decelerating one, since the granulating bed becomes less and less suitable for the support of the ingrowing epithelium; in other words the wound becomes "chronic". When the wound ultimately heals the scar is liable to break down from time to time. In any case, the fibrosis causes undue loss of function.

Wounds of small surface area do not follow this unfortunate course, unless infection is present. Those of intermediate size may often be dealt with by secondary suture. For the remainder, skin grafting is indispensable, since they will not heal well of their own accord beneath the plaster. The best results are never obtained if the application of a plaster cast is the last active surgical treatment given to these patients.

In the past, the major difficulty in secondary skin grafting of granulated wounds has been the presence of infection. This infection can usually be eliminated rapidly by the use of sulphanilamide crystals, and the way is then open for successful skin grafting.

The following technique for treatment of the wound, after the removal of the plaster, incorporates the use of saline baths and of local chemotherapy.[13] The treatment prepares a wound surface for skin grafting, but is equally suitable for those soft tissue wounds which will heal spontaneously or can be secondarily sutured.

Saline baths are given by means of an arm bath, a foot bath or a body bath, once or twice a day, for a couple of hours at a time. The saline solution is normal or hypertonic (2%), and the temperature is maintained at about 90° C. The patient may experience some discomfort on taking the first bath, but subsequently he tolerates the treatment well, and may smoke, read or eat during the bath.

Once the dressings become thoroughly wet, they float off with little assistance. The attendant then removes slough and debris, with the help of forceps. Active movements of the injured part are undertaken so as to prevent loss of function.

The bath is a medium for the spread of infection from one patient to another, unless it is adequately sterilized after use. This can be done by washing with some abrasive cleaner and then scrubbing with 10% lysol solution. Chipped areas cannot be sterilized in this way, and must be reenamelled.

After the bath has been given, further débris is removed and crystalline sulphanilamide is applied. It is regarded as important that the surface to which the sulphanilamide is added should be moist. *Tulle gras* makes an ideal dressing, since it is non-adherent, and permeable to surface discharge. Outside it are placed saline packs which are moistened from time to time with normal saline solution, so that they are always wet. The whole is wrapped firmly.

The procedure is varied if the infecting organism is not the hæmolytic streptococcus. Sulphanilamide is not used, and the saline solution is replaced by eusol. If the organism has been identified as *Bacillus pyocyaneus*, a 2% solution of acetic acid is used as a dressing for a couple of days. The duration of the above treatment, when used as a preparation for skin grafting, is about seven days, but the exact length is determined by clinical and bacteriological examination.

The razor graft is the most suitable type for this work. If the area to be covered is very large, however, or if the patient will not tolerate an anæsthetic well, it may be necessary to use pinch grafts. These are confined to the non-exposed areas of the body.

INFECTION OF RECENT WOUNDS.

It is now generally accepted that the substances which find their way into a wound at the time of its infliction are not usually the source of streptococcal infection, although they may introduce anaerobes. A carrier of streptococci may have the organisms on his skin, and so become infected at the time of wounding, but frequently the fresh wound is sterile. The infection is of the "hospital" or "secondary" type. It is said that 5% of burns are initially infected, but the figure arises to 70% after the patient's admission to hospital. This transfer of organisms between patient and patient, and between staff and patient, had previously been demonstrated in the obstetric hospital and the scarlet fever ward, but its extent in the surgical ward had not been fully realized. In the surgery of peace time it is easy to overlook the factor of wound infection. Striking cases of the transfer of organisms to a wound in hospital are then rare, and may be attributed to unavoidable accident. The infections caused are seldom fatal, or otherwise spectacular. Many are so mild and non-specific that the clinician finds no difficulty in explaining them without incriminating the method of hospital management.

In the treatment of war casualties, however, the factor of cross infection becomes more obvious. The process is a cumulative one, since the larger the number of people with infected wounds, the greater are the opportunities for the spreading of infection. The War Wounds Committee of the Medical Research Council recently found that 70% of the war wounds being treated in London hospitals were

infected with hæmolytic streptococci. Even in the war of 1914-1918, it was realized that secondary sepsis was the chief contributor to delayed healing and crippling complications, but the source of the organisms was not obvious.

The demonstration of hospital infection has been carried out in two ways. It has been shown that fresh wounds are frequently sterile, whereas there is widespread infection amongst the wounds nursed in hospital. It may be claimed that the organisms have merely increased in numbers and so become more obvious. Against this, however, is the fact that it is often three weeks before the hæmolytic streptococcus is recovered from a wound, and this organism does not usually lie in a wound without developing. A second line of evidence comes from the tracing of indicator organisms in their passage through a ward. Hæmolytic streptococci are followed in these investigations, because, although the staphylococci are commoner, the streptococci can be divided into more than thirty types and so an individual type is easily traced. In one typical case a patient with type twelve, Group A, streptococci entered hospital. Within a short time fourteen patients had developed type twelve, Group A, streptococci in their wounds. In six of these skin grafts failed; in some of the others cellulitis and delayed healing occurred. No surgeon could have this experience without being moved to action.

It has been found that the organisms reach wounds by three main channels: contact of the wound with infected hands or utensils; droplet infection from throats; and carriage by the dust of the air. Meticulous care is required to deal successfully with these three factors, but such care has come to be recognized as an elementary requirement due to the patient, rather than as a troublesome farce. The precautions taken should not be made into a ritual, even if they have to become a routine; otherwise there is a danger that the principles on which they are based may be forgotten, and any changes required may cause either bewilderment or annoyance.

To guard against contamination of the wound by infected hands, the fingers of the dresser should not be allowed to touch the wound. Sterile forceps are used to handle the dressings. The hands must be kept dry; if this is observed, special "scrubbing-up" and the use of gloves are unnecessary.

To prevent droplet infection, masks must be worn by all those who attend the dressing or examine the wound. Unauthorized persons are best kept away from the dressings, and members of the staff with infected hands or throats are sent off duty. These regulations should apply to the medical as well as to the nursing staff. The masks worn must cover the nose, come well under the chin, and be impermeable to droplets.

The bacterial count of the air rises to a peak during bed-making and sweeping, and then gradually decreases, as the dust settles. Therefore, wounds should not be dressed within one hour of these two procedures. During the dressings windows and doors should be closed. Spindle oil may be applied to the floor to lay dust, and a finer grade of white oil may even be used on bed-clothes. Soiled articles such as used bed linen and dressings should be put under cover and not left lying around.

Plaster casts become infected and constitute a problem. They may be changed if there is no surgical contra-indication to so doing; otherwise they should be wrapped

in sterile coverings. The removal of plasters should not be done in the ward. Above all, exposure of the wound should be minimal as regards both the number of dressings and the care taken at any individual dressing.

Precautions regarding asepsis have been fairly strictly observed in the operating theatres for about fifty years; but the spirit of these methods is often not carried over into the out-patient department. In the wards, the rules are easy to observe during the formal visits of the surgeon, though he may be guilty of taking a quick glance at a wound; but perhaps the greatest improvement will result from careful attention to the technique of wound dressing. There should be one nurse—the "clean" nurse—to look after the trolley and its contents, and to supply the dresser with sterile materials. She should touch only her sterile forceps with her hands, throughout the round, and need wash only at the beginning and the end of the round. The dresser must wash after she has removed the outer dressings and after she has applied the final bandage. In the meanwhile she, too, uses sterile forceps for her manipulations.

WOUND HEALING.

Wound healing is a complex problem. It is a form of tissue growth, and, therefore, its nature is just as obscure as that of cellular multiplication in general. Some progress has been made recently, however, in understanding the effect on healing of adequate amounts of two dietary constituents—protein and vitamin C.

Low protein intake interferes with healing in two ways. In the first place, it deprives the proliferating cells of the amino acids they require for building purposes. In the second place, it tends to cause œdema in the poorly supported tissues of the wound. The œdema in turn restricts the local blood supply, and so retards healing.

The importance of vitamin C has been finally proved by an experiment on a human volunteer. The subject remained for six months on a diet with a very low vitamin C content. At the end of three months, a wound was made in the skin of his back. It healed normally. A similar wound made at the end of six months, however, healed very poorly, and sections made from the tissues at its edges showed that there was a deficiency of intercellular material. The experiment was concluded by showing that administration of vitamin C parenterally quickly brought about healing, and produced a normal histological picture in the tissues of the wound edge. The effect of lack of vitamin C is therefore a marked one, but the healing of wounds is not affected for some three months after the removal of vitamin C from the diet.

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